COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER
NOAA Hurricane Forecasting
October 7, 2005
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Purpose:
On October 7, 2005 at 10:00 a.m., the House Science Committee will hold a hearing on hurricane forecasting by the National Oceanic and Atmospheric Administration (NOAA). The Committee is holding the hearing to better understand the prediction of hurricanes and the outlook for the remainder of the 2005 hurricane season.

The Committee plans to explore several overarching questions:

1. What are the different responsibilities of the National Hurricane Center and local weather forecast offices when a tropical storm or hurricane threatens the United States?

2. What were the timelines of Katrina and Rita progressing from tropical depressions to major hurricanes and when were warnings issued to the public and to Federal, State and local officials? Was there any difference in how the National Weather Service forecast and issued warnings for these two major hurricanes?

3. What is the outlook for the remainder of the 2005 hurricane season and for the next five to 10 years? Are we in a period of increased hurricane frequency and/or intensity? If so, what is the likely cause of this increase?

4. What can be done to improve prediction of hurricanes, both in the short-term and in the long-term?

Witnesses:
Brigadier General David L. Johnson (ret.), Director of NOAA's National Weather Service.
Mr. Max Mayfield, Director of the National Weather Service's National Hurricane Center.

Background:

What are Hurricanes?
The terms **"**hurricane" and **"**typhoon" are regionally specific names for a strong "tropical cyclone.**"** A tropical cyclone is the generic term for a low-pressure weather system over tropical or sub-tropical waters with organized thunderstorm activity. Tropical cyclones with maximum sustained surface winds of less than 39 mph are called "tropical depressions." Once the tropical cyclone reaches winds of at least 39 mph, it is called a "tropical storm" and assigned a name. If winds reach 74 mph then the storm is called a "hurricane" in the Atlantic Ocean or a "typhoon"

in the Pacific Ocean. Typically, the more intense a tropical cyclone is, the less area it covers. Hurricane Katrina was unusual in that it both was very intense and very large (400 miles across).

The United States utilizes the Saffir-Simpson hurricane intensity scale to give an estimate of the potential flooding and damage to property given a hurricane's estimated intensity. The scale is summarized in Appendix A.

How Hurricanes are Forecast

In the United States, the Atlantic hurricane season is from June 1 to November 30. The National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce, has responsibility "to provide weather, hydrologic, and climate forecasts and warnings for the United States, its territories, and adjacent waters, for the protection of life and property and the enhancement of the national economy."[1] The National Hurricane Center in Miami, which is part of NWS, monitors and forecasts tropical storms and hurricanes in the Atlantic and Northeast Pacific oceans.

The National Hurricane Center (NHC) compiles data about ocean temperature, wind speed and direction, barometric pressure, and other factors and enters that data into computer models to forecast hurricanes. This data is obtained from satellites, ocean buoys and radars. Also, a large amount of data comes from sensors dropped by "hurricane hunter" airplanes as they fly into the storms. Hurricane hunters are flown by the Air Force and NOAA out of Keesler Air Force Base in Mississippi and MacDill Air Force Base in Florida. The planes are modified to carry weather instruments to measure wind, pressure, temperature and dew point and to drop instrumented sensors into hurricanes. When a storm is within three days of potential landfall, hurricane hunters fly into the storm once every six hours.

When tracking a tropical storm or hurricane, the NHC issues official forecasts and warnings every six hours. As a storm nears landfall, the forecasts are updated more frequently. The information goes out to the public via the internet (http://www.nhc.noaa.gov/) and through NOAA Weather Radio. NOAA Weather Radio is a nationwide network of radio stations broadcasting continuous weather information from nearby National Weather Service offices. Every six hours, the NHC also provides (via conference calls and the internet) "technical discussion products" tailored to Federal, State, and local emergency managers and decisionmakers. Local weather forecast offices use the information from the NHC to provide advisories tailored to their region. An example of a tailored hurricane advisory from the New Orleans weather forecast office is provided in Appendix B. Whenever a hurricane threatens U.S. territory, the Federal Emergency Management Agency (FEMA) activates the Hurricane Liaison Team (HLT). This team consists of Federal, State and local emergency managers, NWS meteorologists and computer specialists who help the NHC rapidly exchange information with Federal, State and local emergency managers. The HLT works directly out of the NHC in Miami. For Hurricane Katrina, the HLT was activated on Wednesday, August 24.

Timeline of Hurricane Katrina and Hurricane Rita and NWS Warnings to Federal, State and Local Officials

Hurricane Katrina made landfall on the southeast corner of Louisiana at 6:10 am Central Daylight Time (CDT) on Monday, August 29 as a Category 4 storm (maximum sustained winds

[1] from NWS mission, http://www.nws.noaa.gov/admin.php

of 145 mph) that was unusually large, measuring approximately 400 miles across. At 11:00 pm (CDT) on Friday, August 26, 56 hours before Katrina made landfall, the National Weather Service forecast the storm hitting near New Orleans as a Category 4 or 5 hurricane. NWS was very accurate with its forecast and the final landfall location was only 20 miles off from Friday's forecast. Since meteorological conditions that affect the track and intensity of the storm were relatively stable, NWS was especially accurate in forecasting Katrina.

Between 7:00 and 8:00 pm CDT on Saturday August 27, 35 hours before landfall, the director of the National Hurricane Center called State officials in Louisiana, Mississippi, and Alabama. At 7:00 am on Sunday, August 28, NWS advisories stated that Katrina was a "potentially catastrophic" storm. A more detailed description of Katrina's development from tropical storm to hurricane and the associated warnings are provided in Appendix C.

Hurricane Rita made landfall near Port Arthur, TX around 2:30 am CDT on Saturday, September 24 as a Category 3 storm (maximum sustained winds of 120 mph) and measuring 170 miles across. At 4:00 pm CDT on Tuesday, September 20, the National Weather Service began warning that northwestern regions of the Gulf of Mexico should prepare for a major hurricane.

Hurricane Katrina and Hurricane Rita Compared to Previous Major Storms

While Hurricane Katrina was over the Gulf of Mexico, NOAA measured winds reaching 175 mph, making it the strongest hurricane ever measured in the Gulf of Mexico. By the time it hit the Gulf Coast, Katrina's decreased to 145 mph, down to a Category 4 level but still a very strong storm. There have been three previous category 5 storms (1935 Labor Day storm, Florida Keys; 1969 Camille, Mississippi; and 1992 Andrew, south Florida) to hit the U.S. and six previous Category 4 storms (2004 Charley, 1989 Hugo, 1961 Carla, 1960 Donna, 1957 Audrey, 1954 Hazel) to hit the U.S. The last major storm affecting New Orleans was Hurricane Betsy in 1965, during which winds hit 125 mph before equipment failed. Hurricane Camille (August 1969) was also a major hit but made landfall east of the city and was a more compact storm than either Betsy or Katrina. Hurricane Katrina was unusual in that it was both very intense and large.

Typically, major hurricanes begin in the eastern Atlantic ocean near Cape Verde in western Africa, providing forecasters many days to track, study, and warn of the storms before they threaten U.S. coasts. Since records have been kept, 85 percent of major Atlantic hurricanes have originated from the eastern Atlantic. However, this year all nine tropical depressions that developed intro hurricanes did not form until the systems were west of 55 degrees longitude (near Barbados), providing forecasters only a couple of days to study the storms and citizens less time to prepare their homes.

The last time such a large percentage of hurricanes formed in the western Atlantic was in 1969, when 10 of 12 hurricanes formed west of 55 degrees latitude. That was the year Hurricane Camille struck New Orleans. Scientists can determine after the fact that the factors favoring quick formation of hurricanes in the Caribbean are a combination of favorable wind patterns and sea surface temperatures, but scientists cannot predict these patterns ahead of time.

Outlook for Future Hurricanes

Hurricane Rita was the 13th named storm of the 2005 hurricane season. Typically the month of September is the peak month for hurricane activity. Through November 30 (end of hurricane season), NOAA expects seven to 10 additional named storms, of which one to three could be major hurricanes of Category 3 strength or higher. The chance of one of those major hurricanes making landfall somewhere in the U.S. is 21 percent. However, it is difficult to predict exactly where a hurricane would hit because the path of a hurricane is primarily determined by day-to-day weather patterns. Historically, weather patterns in October push tropical storms north from the Caribbean and back out to sea, decreasing the chances that the Gulf Coast will be hit by another hurricane. However, there is still a chance that the Gulf could see another storm this year.

Most scientists agree that the Atlantic Ocean is currently in a period of increased hurricane activity, which is part of a natural 25- to 40- year cycle known as the "Atlantic multi-decadal signal," a shift in the sea surface temperatures in the Atlantic. Warmer sea surface temperatures combined with optimal wind conditions cause more tropical depressions to develop into hurricanes. Scientists are unsure of the cause of the natural temperature and wind shifts in the Atlantic. The last period of high tropical Atlantic activity was 1920-1966. The average number of hurricanes in a warm period is 10 per year, while the average number of hurricanes in a cold period is six storms per year. Today, many more people live in hurricane prone areas than during the last period of high tropical activity, meaning that today's storms will affect more people and cause more damage than historical storms. Appendix D contains more detail on the Atlantic multi-decadal signal and hurricane frequency.

While most scientists agree that the current increase in hurricane frequency is not due to global climate change, over the next 50 years hurricane intensity (not frequency) could increase as ocean temperatures rise. Also, two recent studies have shown some evidence that current hurricane intensity has slightly increased since 1970. The first study, published in *Nature* in July, looked at the North Atlantic Ocean and found that hurricane intensity has increased 50 percent in the past 50 years[1]. The second study, published in *Science* in September, looked globally at all oceans and found that the number of category 4 and 5 hurricanes has nearly doubled each decade since 1970, while the total number of hurricanes has remained constant[2].

Improving Hurricane Forecasts

In 1954, the NHC first issued one-day forecasts of hurricanes. Since 1964, the NHC has provided three-day hurricane forecasts. In 2003, the forecasts were extended to include five-day predictions. Appendix E contains examples of the five- and three- day forecasts for Hurricane Katrina. Today, a three-day forecast is as accurate as those issued for a two-day prediction in the late 1980s. While NHC has significantly improved the forecast of where a hurricane is likely to go, the forecasts of hurricane intensity have not improved at the same pace.

NOAA currently supports research in its own labs and provides grants to universities to try to improve hurricane forecasts. Other agencies that support this type of research include the National Science Foundation and the National Aeronautics and Space Administration. The most useful information to researchers comes from taking observations from hurricane hunter

[1] K.A. Emmanuel, *Nature*, **436**, 686 (2005)
[2] P.J. Webster, G.J. Holland, J.A. Curry, H.R. Chang, *Science* **309**, 1844 (2005)

airplanes and ocean buoys during a real hurricane, which can be used to develop new forecasting models. As Congress debates supplemental spending and regular agency budgets, some experts think an additional hurricane hunter airplane equipped with research sensors would help researchers improve computer models of hurricane intensity. (Also, NOAA lost some facilities during Hurricane Katrina and may require additional funding to rebuild those facilities.)

NOAA Hurricane Forecasting and Research Funding History (dollars in millions)

NOAA Office/ Program	**FY2004**	**FY2005**	**FY2006 request**	**FY2006 House**	**FY2006 Senate**
National Weather Service	$827	$783	$840	$842	$863
National Hurricane Center (subset of NWS total budget)	$4.9	$5	$5.2	Not specified*	Not specified*
NOAA Hurricane Research	$9.7	$12	$10	Not specified*	Not specified*
NOAA Satellites Service	$814	$907	$964	$968	$1000

*The House and Senate appropriations bills only contain a number for the National Weather Service overall and do not detail specific spending for NHC or for all hurricane research.

Witness Questions:
The witnesses were asked to address the following questions in their testimony.

1. What are the different responsibilities of the National Hurricane Center and local weather forecast offices when a tropical storm or hurricane threatens the United States?

2. What were the timelines of Katrina and Rita progressing from tropical depressions to major hurricanes and when were warnings issued to the public and to Federal, State and local officials? Was there any difference in how the National Weather Service forecast and issued warnings for these two major hurricanes?

3. What is the outlook for the remainder of the 2005 hurricane season and for the next five to 10 years? Are we in a period of increased hurricane frequency and/or intensity? If so, what is the likely cause of this increase?

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Appendix A: Summary of Saffir-Simpson Hurricane Scale

Saffir-Simpson Hurricane Scale
Category 1 (Minimum Damage): Maximum sustained wind speed, 74-95 mph; storm surge 3-5 feet
"Damage primarily to shrubbery, trees, foliage, and unanchored homes. No real damage to other structures. Some damage to poorly constructed signs. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings."
Category 2 (Moderate Damage): Maximum sustained wind speed, 96-110 mph; storm surge 6-8 feet
"Considerable damage to shrubbery and tree foliage; some trees blown down. Major damage to exposed mobile homes. Extensive damage to poorly constructed signs. Some damage to roofing materials of buildings; some window and door damage. No major damage to buildings. Coast roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation of some shoreline residences and low-lying areas required."
Category 3 (Extensive Damage): Maximum sustained wind speed, 110-130 mph; storm surge 9-12 feet
"Foliage torn from trees; large trees blown down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some wind and door damage. Some structural damage to small buildings. Mobile homes destroyed. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Flat terrain 5 feet or less above sea level flooded inland 8 miles or more. Evacuation of low-lying residences within several blocks of shoreline possibly required."
Category 4 (Extreme Damage): Maximum sustained wind speed, 131-155 mph; storm surge 13-18 feet
"Shrubs and trees blown down; all signs down. Extensive damage to roofing materials, windows and doors. Complete failures of roofs on many small residences. Complete destruction of mobile homes. Flat terrain 10 feet or less above sea level flooded inland as far as 6 miles. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Major erosion of beaches. Massive evacuation of all residences within 500 yards of shore possibly required, and of single-story residences within 2 miles of shore."
Category 5 (Catastrophic Damage): Maximum sustained wind speed, 156+ mph; storm surge 19+ feet
"Shrubs and trees blown down; considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors. Some complete building failures. Small buildings overturned or blown away. Complete destruction of mobile homes. Major damage to lower floors of all structures less than 15 feet above sea level within 500 yards of shore. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Massive evacuation of residential areas on low ground within 5 to 10 miles of shore possibly required."

Appendix B: New Orleans Weather Forecast Office Hurricane Katrina Advisory

Urgent Weather Message

National Weather Service
New Orleans, LA

1011 AM CDT

Sun Aug 28 2005-09-07

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Devastating damage expected

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Hurricane Katrina … A most powerful **hurricane** with unprecedented strength … rivalling the intensity of **Hurricane Camille** of 1969.

Most of the area will be uninhabitable for weeks … perhaps longer. At least one half of well-constructed homes will have roof and wall failure. All **gabled** roofs will fail … leaving those homes severely damaged or destroyed.

The majority of industrial buildings will become non-functional. Partial to complete wall and roof failure is expected. All wood-framed low-rising apartment buildings will be destroyed. Concrete block low-rise apartments buildings will sustain major damage … including some wall and roof failure.

High-rise office and apartment buildings will sway dangerously … a few to the point of total collapse. All windows will blow out.

Airborne debris will be widespread … and may include heavy items such as household appliances and even light vehicles. Sport utility vehicles and light trucks will be moved. The blown debris will create additional destruction. Persons … pets … and livestock exposed to the winds will face certain death if struck.

Power outages will last for weeks … as most power poles will be down and **transformers** destroyed. Water shortages will make human suffering incredible by modern standards.

The vast majority of native trees will be snapped or uprooted. Only the heartiest will remain standing … but be totally defoliated. Few crops will remain. Livestock left exposed to the winds will be killed.

An inland hurricane wind warning is issued when sustained winds near hurricane force … or frequent gusts at or above hurricane force … are certain within the next 12 to 24 hours.

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Once tropical storm and hurricane force winds onset … do not venture outside!

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Appendix C: Hurricane Katrina and Hurricane Rita Timelines

Hurricane Katrina

- 4:00 pm CDT Tuesday August 23: First public advisory of Tropical Depression Twelve.
- 7:00 am CDT Wednesday August 24: FEMA activated the Hurricane Liaison Team.
- 10:00 am CDT Wednesday August 24: Tropical Depression Twelve develops into Tropical Storm Katrina over the Bahamas.
- 2:30 pm CDT Thursday August 25: Tropical Storm Katrina develops into Hurricane Katrina, located 15 miles off the coast of Ft. Lauderdale, FL.
- 5:30 pm CDT Thursday August 25: Hurricane Katrina makes landfall as a Category 1 hurricane on the southeast coast of Florida. As it passes over Florida it weakens back down to a tropical storm and moves into the Gulf of Mexico.
- 4:00 am CDT Friday August 26: After passing over Florida, Katrina regains hurricane status over the Gulf of Mexico.
- 11:00 pm CDT Friday August 26: Every NWS warning beginning Friday evening, 56 hours before landfall, showed Hurricane Katrina making landfall in southeastern Louisiana as a category 4 or 5 hurricane.
- 10:00 am CDT Saturday August 27: At 44 hours before landfall, the NWS issued a hurricane watch including New Orleans. A hurricane watch advises of possible hurricane conditions, with the objective of providing 36 hours notice. The watch for Katrina surpassed that objective by 8 hours.
- 4:00 pm CDT Saturday August 27: At 42 hours before landfall, the hurricane watch was extended to Mississippi and Alabama.
- 7:25 pm CDT Saturday August 27: Max Mayfield (Director of the National Hurricane Center) called Gov. Blanco of Louisiana.
- 7:35 pm CDT Saturday August 27: Max Mayfield called Bill Filter, Chief of Operations for Alabama Emergency Management Agency.
- 7:45 pm CDT Saturday August 27: Max Mayfield called Gov. Barbour of Mississippi.
- 8:00 pm CDT Saturday August 27: Max Mayfield called Mayor Nagin of New Orleans.
- 10:00 pm CDT Saturday August 27: At 32 hours before landfall, the NWS issued a hurricane warning that included New Orleans. A hurricane warning advises that a hurricane will likely hit, with the objective of providing 24 hours lead time. The watch for Katrina surpassed that objective by 8 hours. Every NWS warning beginning Saturday evening, 32 hours before landfall, stated that "Preparations to protect life and property should be rushed to completion" and predicted coastal storm surge of at least 15 to 25 feet.
- 7:00 am CDT Sunday August 28: Every NWS warning beginning 23 hours before landfall, began with the headline indicating that Hurricane Katrina could be "Potentially Catastrophic." Due to the advanced warning provided by NWS, a mandatory evacuation was put in place for New Orleans on Sunday morning (24 hours before landfall) and the President declared a state of emergency on Sunday, meaning that Louisiana could use Federal resources before the hurricane hit. Typically, the President waits until after an event.

Appendix C: Hurricane Katrina and Hurricane Rita Timelines (continued)

Hurricane Rita

- 10:00 pm CDT Saturday September 17: First public advisory of Tropical Depression 18.
- 6:00 am CDT Sunday September 18: FEMA activates the Hurricane Liaison Team.
- 4:00 pm CDT Sunday September 18: Tropical Depression 18 develops into Tropical Storm Rita.
- 10:00 pm CDT Sunday September 18: Hurricane and tropical storm warnings issued for southern Florida.
- 10:00 pm CDT Monday September 19: Rita is predicted to strengthen to a Category 2 hurricane before hitting Florida.
- 10:00 am CDT Tuesday September 20: Rita elevated to a Category 1 hurricane.
- 1:00 pm CDT Tuesday September 20: Rita elevated to a Category 2 hurricane as it moves over Florida.
- 4:00 pm CDT Tuesday September 20: At 82 hours before landfall, NWS warns that "all indications are that Rita as an intense hurricane will be approaching the Texas Coast in about 3 days."
- 10:00 pm CDT Tuesday September 20: NWS warns that Rita could reach Category 4 status by Wednesday evening.
- 1:00 am CDT Wednesday September 21: Rita elevated to a Category 3 hurricane.
- 6:00 am CDT Wednesday September 21: Rita elevated to a Category 4 hurricane.
- 10:00 am CDT Wednesday September 21: At 64 hours before landfall, NWS states that "interests in the northwestern Gulf of Mexico should monitor the progress of dangerous Hurricane Rita… Rita is extremely dangerous category four hurricane… some additional strengthening is forecast during the next 24 hours and could reach category five intensity in the central Gulf of Mexico."
- 4:00 pm CDT Wednesday September 21: At 58 hours before landfall, Rita elevated to a Category 5 hurricane. Hurricane and tropical storms watches are posted for Louisiana and Texas.
- 11:00 am CDT Thursday September 22: At 39 hours before landfall, Rita downgraded to a Category 4 hurricane. Hurricane and tropical storms warnings issued for Texas and Louisiana.
- 10:00 am CDT Friday September 23: At 16 hours before landfall, Rita predicted to hit early Saturday morning as either a category 3 or 4 hurricane. Rita is expected to come ashore as "a dangerous hurricane."
- 2:30 am CDT Saturday September 24: Rita makes landfall in extreme southwest Louisiana as a category 3 hurricane (with top winds of 120 mph).
- 7:00 am CDT Saturday September 24: Rita downgraded to Category 2 hurricane
- 10:00 am CDT Saturday September 24: Rita downgraded to Category 1 hurricane.
- 1:00 pm CDT Saturday September 24: Rita downgraded to a tropical storm.
- 8:00 pm CDT Saturday September 24: Rita downgraded to a tropical depression. Last NHC advisory.

Appendix D: Contrast of Atlantic Hurricanes

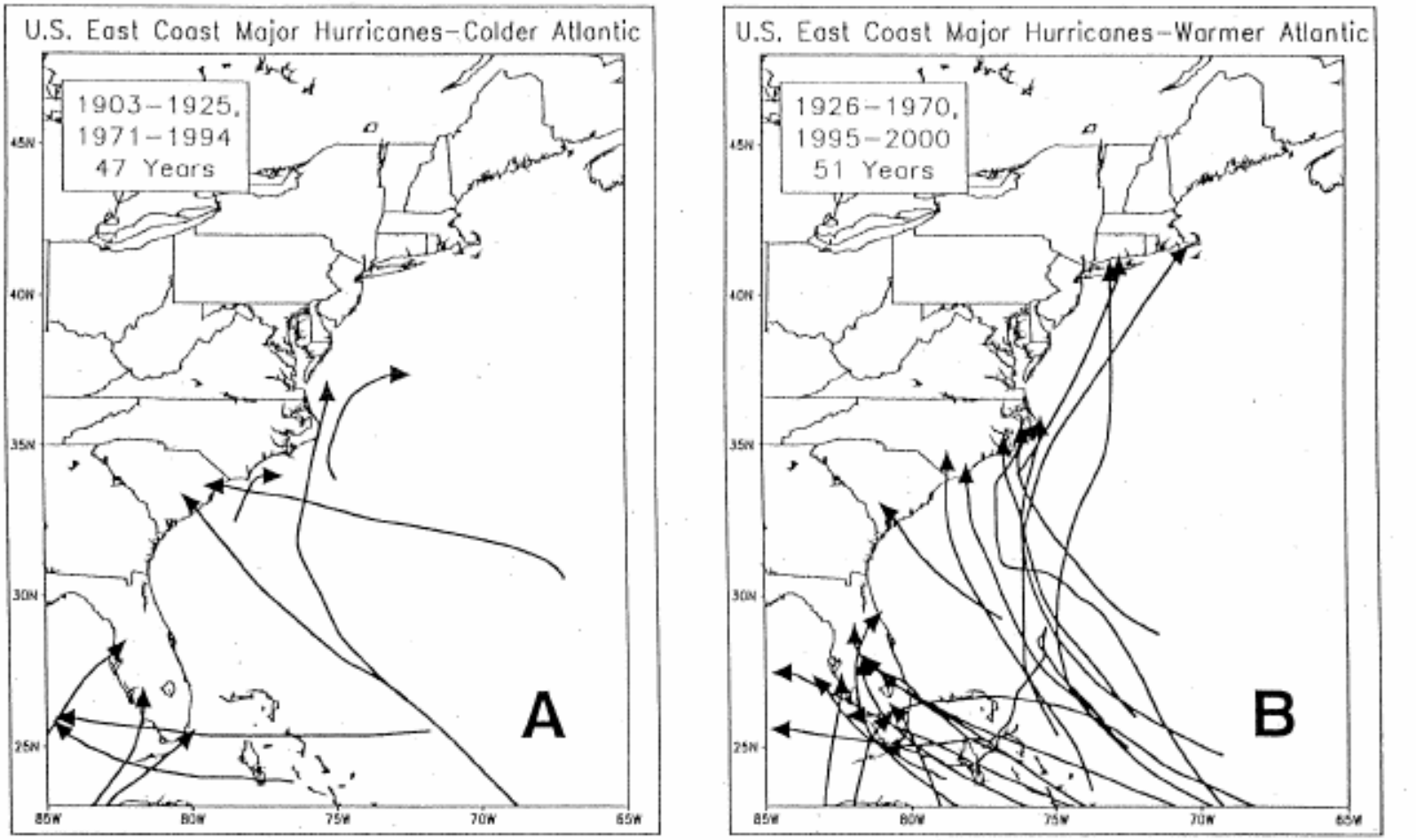
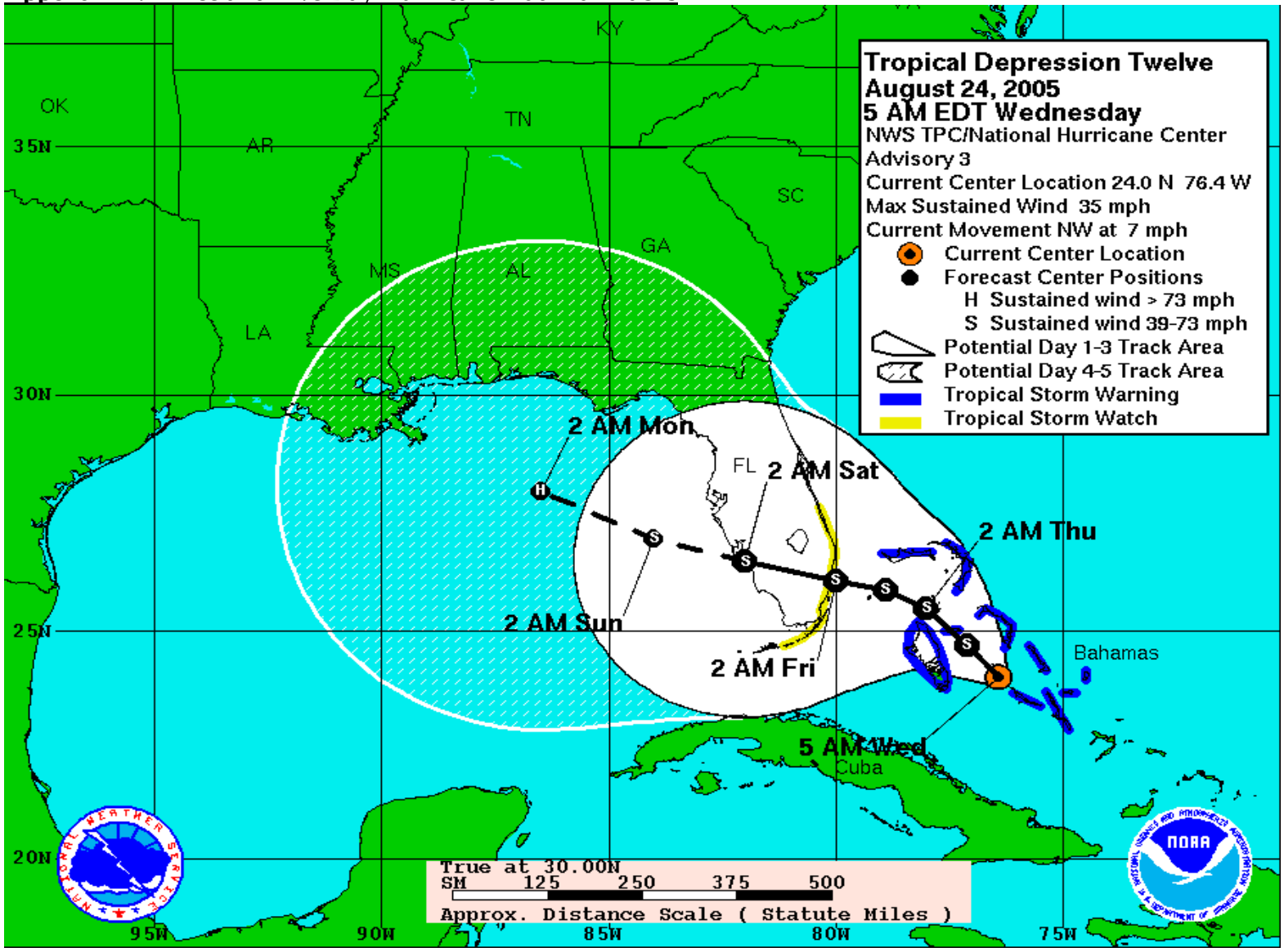
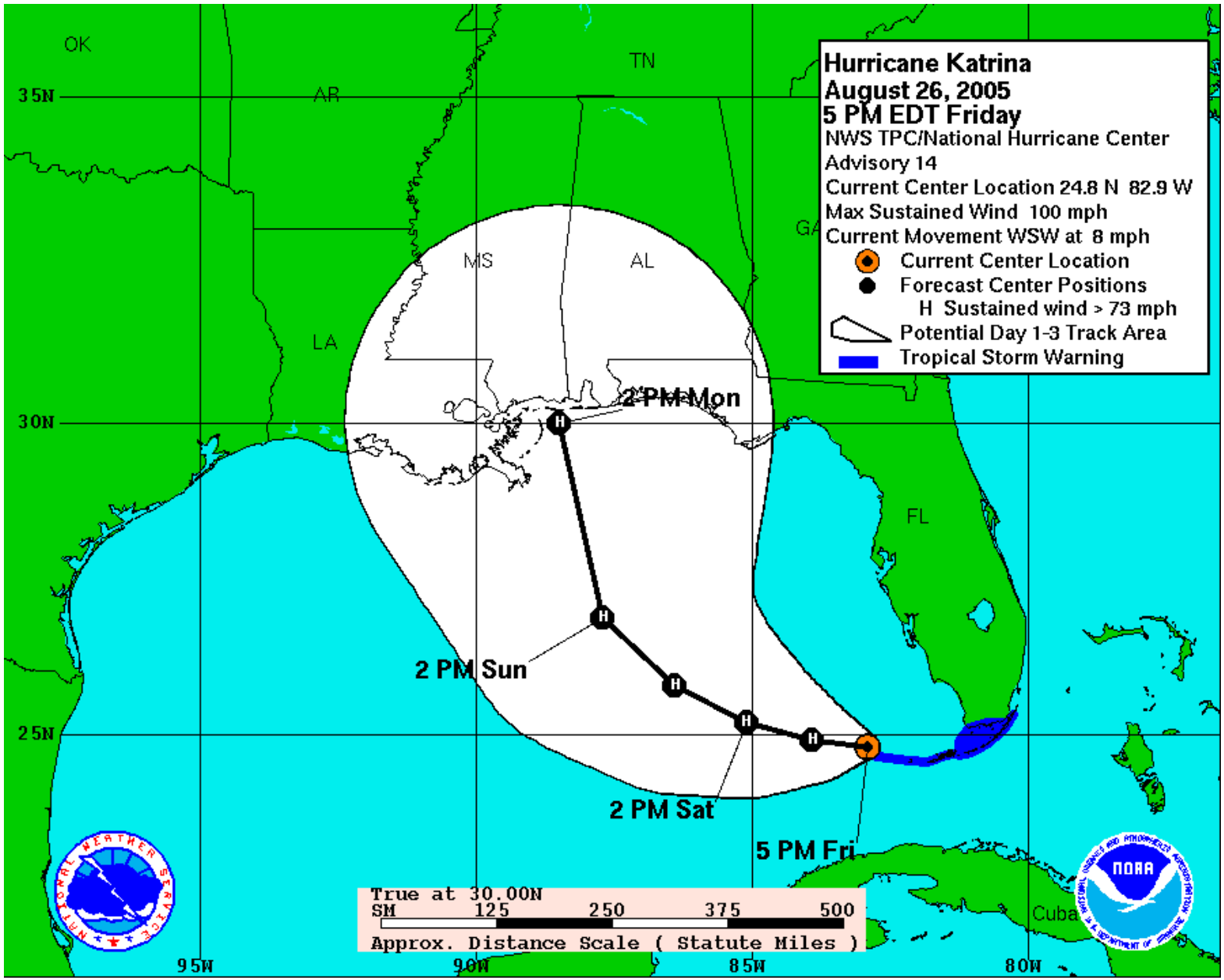


Fig. 5. Contrast of U.S. East Coast major hurricane landfalls for colder (**A**) versus warmer (**B**) values of Atlantic multidecadal mode. The tracks of major hurricanes that affected the U.S. East Coast at that strength are indicated by solid red lines. The years are like those in (*44*) except that the first four warmer years (1899-1902) are not included to make the number of colder and warmer years similar. Colder years (47 years) include 1903-25 and 1971-94. Warmer years (51 years) include 1926-70 and 1995-2000. (From Goldenberg et al., July 20th, 2001, *Science*)

Appendix E: Three and Five Day Hurricane Katrina Tracks




Hurricane Katrina
August 26, 2005
5 PM EDT Friday
NWS TPC/National Hurricane Center
Advisory 14
Current Center Location 24.8 N 82.9 W
Max Sustained Wind 100 mph
Current Movement WSW at 8 mph
Current Center Location
Forecast Center Positions
H Sustained wind > 73 mph
Potential Day 1-3 Track Area
Tropical Storm Warning
OK
AR
TN
MS
AL
LA
GA
FL
Cuba
35N
30N
25N
95W
90W
85W
80W
2 PM Mon
2 PM Sun
2 PM Sat
5 PM Fri
True at 30.00N
SM 125 250 375 500
Approx. Distance Scale (Statute Miles)
NOAA